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Study the Flow Analysis of Hypersonic Vehicle Combustion

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Abstract: *In recent trends, most implausible development was supersonic combustion chamber which operated without any moving parts. Due to the deceleration of the free stream air, the pressure, temperature and density of the flow entering the burner are "considerably higher than in the free stream". At flight Mach numbers of around Mach 6, these increases make it inefficient to continue to slow the flow to subsonic speeds. Thus, if the flow is no longer slowed to subsonic speeds, but rather only slowed to acceptable supersonic speeds, the ramjet is then termed a 'supersonic combustion ramjet,' resulting in the acronym scramjet. In this work the hot flow entering are altered to hypersonic speed, resulting in hypersonic combustion. This condition may be obtained by changing the swirler's into required geometrical shape. Factors such as size, weight, design complexity, maintainability, longevity, storability, production and life cycle costs, and logistic supportability were identified to be just as important as the performance characteristics (speed, range, and efficiency) of the hypersonic vehicle. These are analyzed using computational fluid dynamics software. The results were simulated for different boundary condition with varying blades at* hypersonic speed level and then results will be compared to get positive and negative feedback.

Keywords: *Scramjet, Hypersonic, Computational fluid dynamics*

I. INTRODUCTION

In order to provide the definition of a scramjet engine, the definition of a ramjet engine is first necessary, as a scramjet engine is a direct descendant of a ramjet engine. Ramjet engines have no moving parts, instead operating on compression to slow free stream supersonic air to subsonic speeds, thereby increasing temperature and pressure, and then combusting the compressed air with fuel. Lastly, a nozzle accelerates the exhaust to supersonic speeds, resulting in thrust. Figure 1.shows a two- dimensional schematic of a ramjet engine.

Due to the deceleration of the free stream air, the pressure, temperature and density of the flow entering the burner are "considerably higher than in the free stream". At flight Mach numbers of around Mach6, these increase smoke it inefficient to continue to slow the flow to subsonic speeds. Thus, if the flow is no longer slowed to subsonic speeds, but rather only slowed to acceptable supersonic speeds, the ramjet is then termed a 'supersonic combustion ramjet,' resulting in the acronym scramjet. Though the concept of ramjet and scramjet engines may sound like something out of science fiction, scramjet engines have been under development for at least forty years. The following subsection will give a brief chronological history of the scramjet engine [1-2].

In the supersonic combustion system the proper mixing of fuel-to-air is the major problem faced. This problem is mainly due to lack of turbulence and high Mach number. This paper deals with the flow analysis over a combustion chamber of hypersonic vehicle and overcome the problems in combustor of hypersonic vehicle by varying swirler's geometry [3-5].

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II. Literature Review

The process of reading, evaluating, classifying and comparing the prior research studies, summarizing them and critical analysis of scholarly materials about a specific topic is known as a literature review. It is a critical and an evaluative summary of the themes, issues and crusher of a specific concept clearly defined research topic obtained from the published literature. From the literature review the development of scramjet engine and their technical challenges faced by the engine. The injection systems in the engine and the methods of proper mixing of the fuel and air are explained. The component named swirler and its function has also been described efficiently[5-9].

David B. Ercegovic developed the Flame-Tube Combustor Using CFD analysis. The jet fuel ratio is improved by using SWIRL mounting mixture [1]. Billig review the supersonic combustion for research [2]. In-SeuckJeung and Jeong had developed the supersonic combustion ramjet propulsion engine simulated and analysis the combustion using ansys[3]. Cheng using model the CFD analysis of gas turbine for using low SWIRL injector concept [4]. Christopher simulated the supersonic combustion [5]. Chandara prakash designed the scramjet combustors. It 2D numerical simulation results had compared to quasi one dimensional analysis [6]. Andrew developed the supersonic combustion for CFD modelling [7]. Michael A. Bolender reviewed the modelling of hypersonic vehicle and also discussed the dynamics, controls of hypersonic vehicles [8]. Pandey K.M. and Sakthivel .T CFD Analysis of Mixing and Combustion of a Scramjet Combustor with a Planer Strut Injector

IV. Designing of Swirler

Description

The dome and swirler are the part of the combustor that the primary air flows through as it enters the combustion zone. Their role is to generate turbulence in the flow to rapidly mix the air with fuel. Thus the swirler for various numbers of blades is designed using the CATIA V5 software. Thus the designed model is meshed using the ICEM CFD. The dimension of the swirler obtained from the reference are given below,

- Hub angle 45^0
- Tip angle 60^0
- Hub diameter 100 mm
- Outer diameter 150 mm

From the obtained values the swirler model was designed, meshing
The swirler is imported to ANSYS ICEM CFD and two domains air and solid were created.

Table No.4.1 Mesh Report of Swirler

DOMAIN	NODES	ELEMENTS
Air	117723	610293
Solid	28112	107092
All Domains	145835	717385

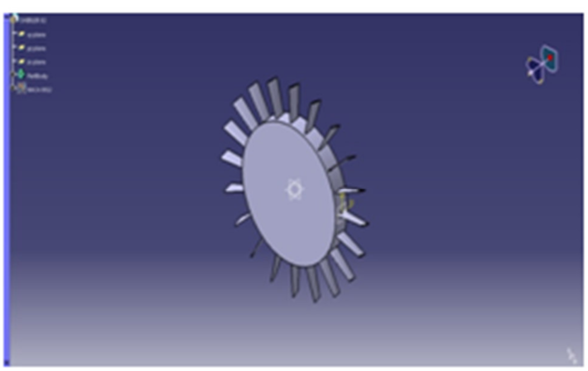

Figure No.1 Swirler Model

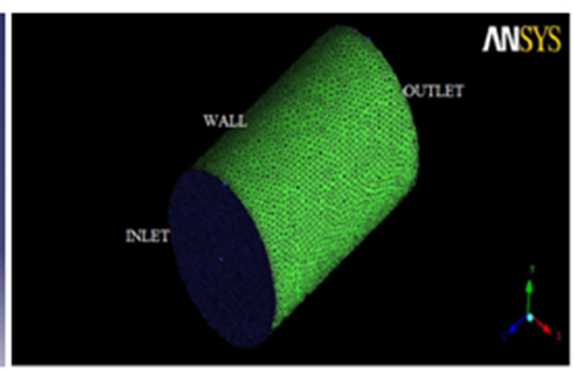

Figure No.2 Meshed View of the Model

Thus the swirler model designed is meshed using ANSYS ICEM CFD and solved using CFX solver and analyzed. The objective of this analysis is to find out a best swirler - blade combination. The number of blades in the swirler is varied from 18 to 22.

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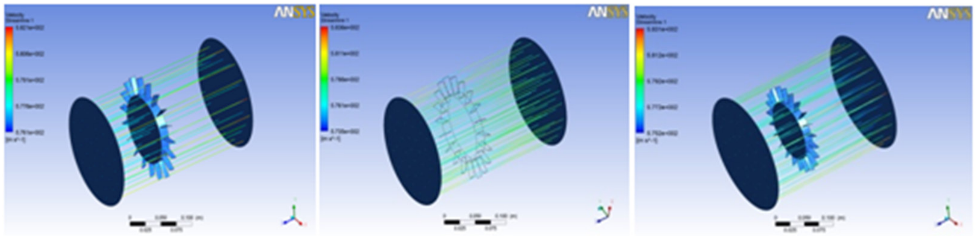


Figure No.3,4,5 Velocity Streamline for 18, 20, 22 Blades

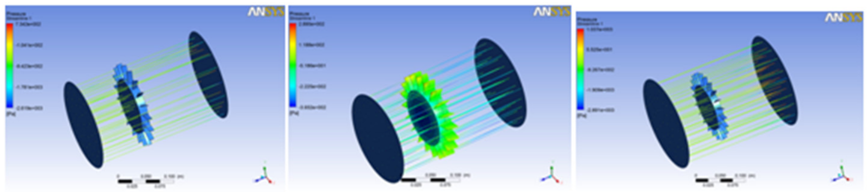


Figure No.6,7,8 Pressure Streamline for 18, 20, 22 Blades

V. Results and Discussion

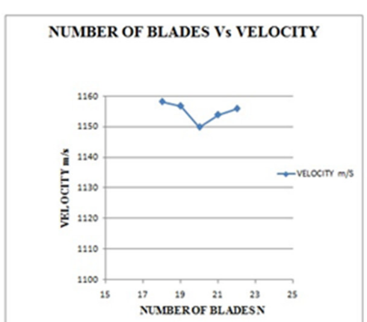
To adapt low-swirl combustion for gas turbines the most pressing question is whether or not this flame stabilization method is operable at elevated temperatures and pressures. Light-off of the LSB was easy even at elevated temperatures and pressures. The obtained results from the numerical analysis are used to determine the fuel-to-air ratio.

It consisted of 20 flat blades inclined 15' relative to the airflow direction. This swirler was the same for all the configurations. The main swirler and main swirler plus the counter swirl insert were flow Cali-brated under ambient conditions in an atmospheric exhaust calibration stand.

Table No.1 Results Obtained From the Analysis

S.NO	NUMBER OF BLADES	PRESSURE Kpa	VELOCITY m/s	FUEL-TO-AIR RATIO
1	18	1.040	1158.2	0.0055
2	19	1.070	1156.8	0.0053
3	20	1.470	1150.0	0.0036
4	21	1.1000	1154.0	0.0043
5	22	1.072	1156.0	0.0046

From the obtained values of the velocity and pressure for different number of blades the X-Y plot graph has been drawn.



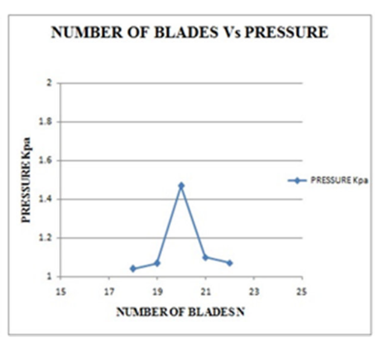


Figure No.9 Number of Blade vs. Velocity Figure No.10 Number of Blade vs. Pressure

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VI. Conclusion

The main problem faced by the scramjet engines are proper mixing of fuel and air and the solution for this problem was concluded by selection of swirler with 20 number of blades. This swirler was able to produce efficient fuel to air ratio compared to other swirlers. The exit velocity of the combustor is also found for the specific swirler using the values of numerical analysis. Thus by placing the swirler at the entrance of the combustion chamber will produce proper mixing of fuel and air and also effective efficiency.

Since there is no end for invention and innovation, in the same way the results can produced in the field of structural analysis. This can also be proceeded by selecting the proper material for the swirler. The angle of twist for swirler blades can also be varied and the results can be produced. The analysis can be performed in numerical methods.

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